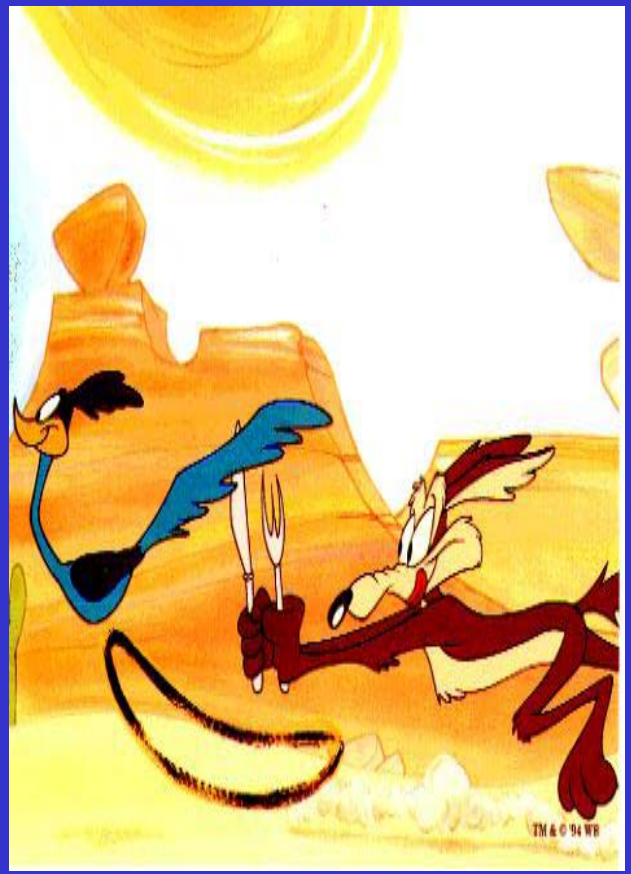
Potential for Controlling Pests with Genetically Modified Forages

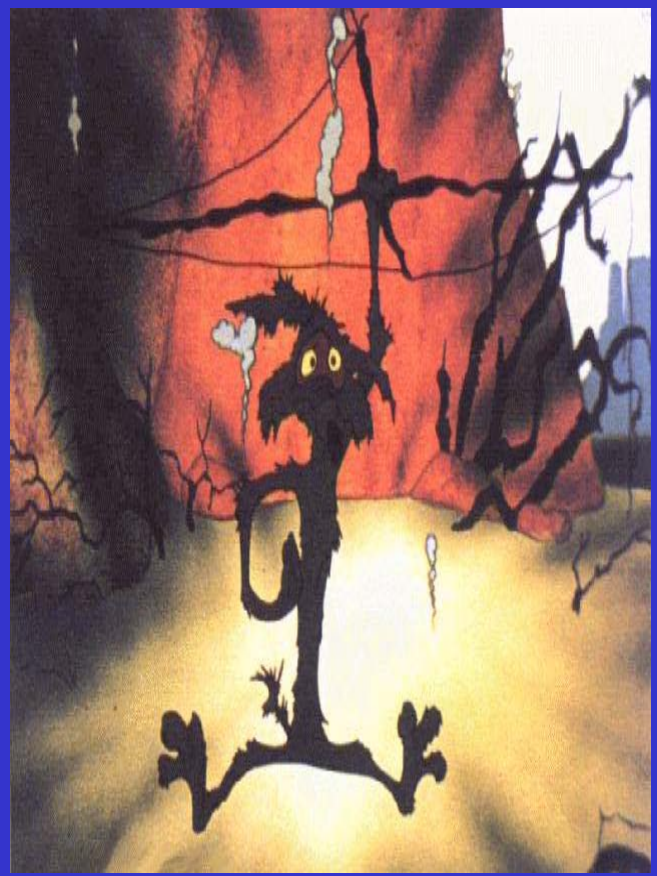
Dr. George J. Vandemark

USDA-ARS, Vegetable and Forage Crop Research Unit

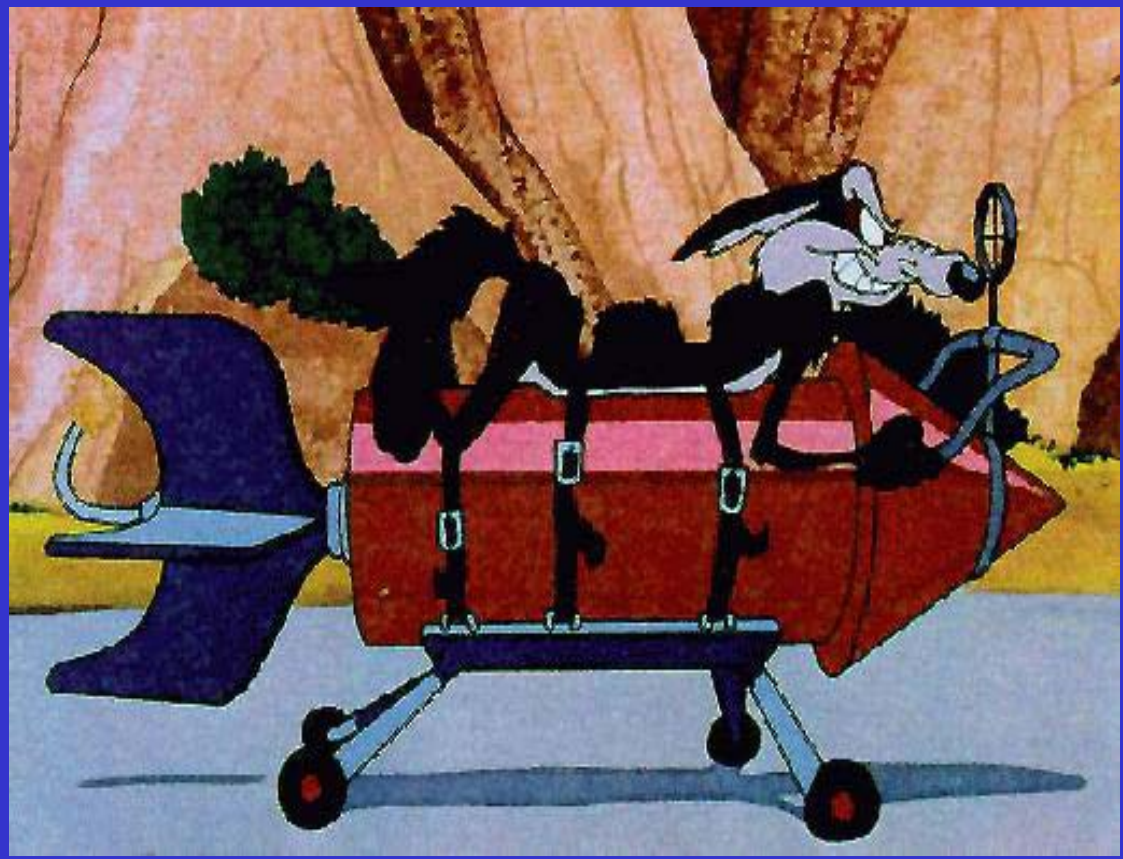
Prosser, WA

Producing and Commercializing Transgenic Forages Will Require Determination!!!





Producing and Commercializing Transgenic Forages Will Require Determination!!!

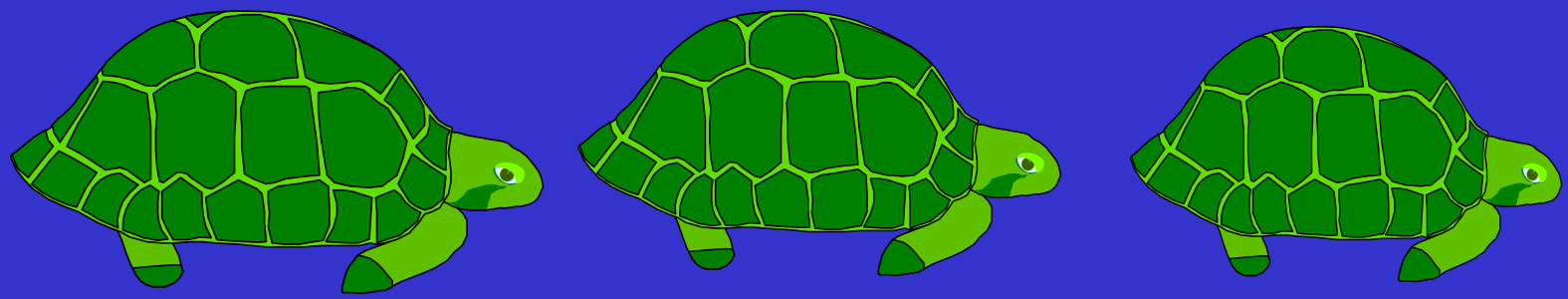


Topics for Discussion

- Forage Research at the USDA-ARS, Prosser, WA
- Overview of Genetic Engineering
- Trait Modification via Genetic Engineering
- Genetic Engineering of Pest/Pathogen Resistance
- Sick Rats, Dead Butterflies
- National/Global Trends in the Acceptance of Transgenic Plants

Limitations of 'Conventional' Plant Breeding

- Plant Breeding is a laborious and time-consuming process.

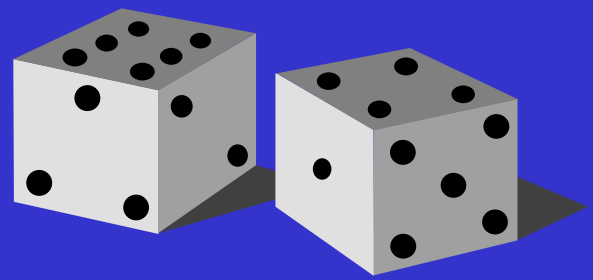


- Sources of 'good genes' often come from wild relatives of crop species and have very poor agronomic characteristics.

Genetic Engineering is the process by which molecular biology techniques are used to speed up the improvement of crop varieties

Producing Genetically Modified Plants requires the Following Steps

- Identify and Clone Gene of Interest
- Transfer Gene (transgene) into Plant Chromosome
- Select for Growth of Plant Cells Having Gene
- ‘Regenerate” Whole Plant by Tissue Culture



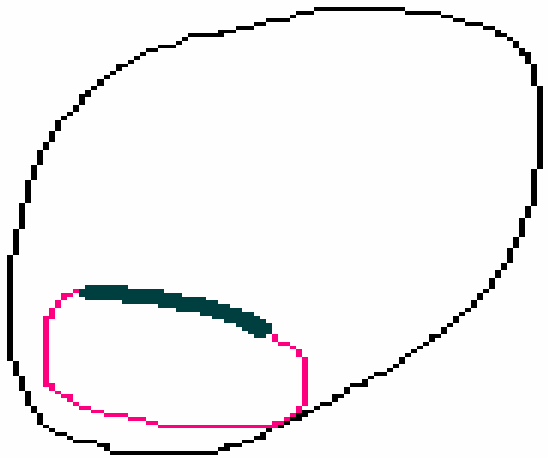
Limitations in the Use of Genetic Engineering to Improve Crop Varieties

- Only effective for modifying traits controlled by single genes.
- Procedures for the insertion of foreign genes or regeneration of whole plants from tissue culture are not effective for all crop species .
- For some crop species, the varieties that can be easily manipulated are commercially worthless (alfalfa) .

Process of Gene Transfer into Plant Tissue

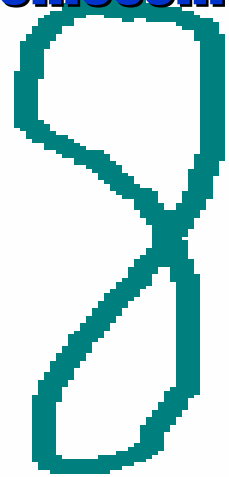
- Manipulation of gene is typically done using the bacteria E. coli.
- The gene is then transferred from E. coli to the plant pathogenic bacteria Agrobacterium tumefaciens.
- A. tumefaciens is used to infect plant parts and the gene is transferred from the bacteria into the plant chromosome.

Gene transfer from bacteria to plants



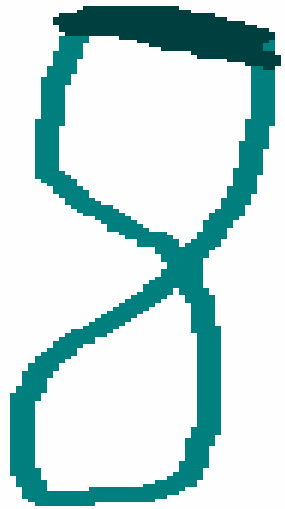
Bacteria + gene

Plant Chromosome



Original

Chromosome



Modified

Benefits of the Use of Transgenic Plants[1]

- Bt Cotton (1998):
  - Planted on 2.3 million acres in US. Reduced pesticide application by over 1 million lbs.
  - Bt cotton farmers increased yields by 37 lbs/acre and made $40/acre more than non-Bt cotton farmers

[1]SCIENCE:1999.286:1666

Benefits of the Use of Transgenic Plants[1]

- Bt Corn (1998):
  - Planted on 14 million acres in US. Pesticide applications were eliminated on only 2 million acres (sprays typically are not effective against corn borer)
  - Increased profits from increased yields did not cover extra cost of the Bt corn seed

[1]SCIENCE:1999.286:1666

Benefits of the Use of Transgenic Plants[1]

- RoundUp Ready Soybean (1998):
  - Allowed farmers to substitute RoundUp for more hazardous herbicides (acetochlor)
  - Reduced the need to use tillage for weed control ∴ less erosion
  - economic results are not conclusive

[1]SCIENCE:1999.286:1666

Traits Modified with Genetic Engineering

- Production Traits
  - Tolerance to abiotic stresses
  - Tolerance to insect pests and pathogens
  - Tolerance to contaminants in soil
- 'Value added' Traits
  - Enhanced shelf life
  - Modified nutritional profiles
  - Phytoremediation

Challenges for the Development of Genetically Modified Alfalfa

- Genetics: alfalfa is tetraploid (4 copies of each chromosome). Will one copy of a transgene produce the desired trait??

- Gene transfer and plant regeneration: Some of the best alfalfa varieties are very difficult to manipulate.

Challenges for the Development of Genetically Modified Alfalfa

- Variety development: Most alfalfa varieties are 'synthetics'=seed is produced from the random mating of select parents (7-200 individual parents).

- It will be necessary to identify parents that:
  - Cross well together and produce good progeny
  - Accept foreign genes and regenerate whole plants

Challenges for the Development of Genetically Modified Alfalfa

- Market considerations:
  - Majority of alfalfa is used by dairies
  - Second order reaction: Will dairies buy genetically modified forages if consumers reject foods prepared using genetic engineering technologies???
  - Public relations, consumer education

Challenges for the Development of Genetically Modified Alfalfa

- Proprietary issues:
  - Virtually all of the technologies involved in making transgenic plants have issues of ownership
    - New genes, DNA domains responsible for correct function of foreign genes in plants (promoters, enhancers, targeting), transformation procedures

Global Cultivation of Transgenic Crops[1] (SCIENCE:1999. 286:1662)

Crop	1998	1999
Soybean	14.5	21.6
Corn	8.3	11.1
Cotton	2.5	3.7
Canola	2.4	3.4
Potato	<0.1	<0.1
Squash	0.0	<0.1
Papaya	0.0	<0.1

[1]Millions of hectares

Global Cultivation of Transgenic Crops (Science:1999. 286:1662)

Trait	1998	1999
Herbicide^{res}	19.8	28.1
Insect$^{res(Bt)}$	7.7	8.9
Virus^{res}/other	<0.1	<0.1
Herb + Insect^{res}	0.3	2.9

American Farm Bureau Federation Poll on Planting of Transgenic Crops for 2000

- RoundUp Ready Soybeans down 15%
- RoundUp Ready Corn down 22%
- Bt Corn down 24%
- Bt Cotton down 26%
- RoundUp Ready Cotton up 5%
- Monsanto spokesman Dan Verakis: “seed sales will be consistent with 1999”

Factors Cited by Growers as Influencing Their Decision on Growing Transgenic Crops[1]

- Consumer concerns about safety of GMOs
- European and Asian buyers are offering premiums for non-GM Crops
- International buyers are requiring segregation of GM and non-GM commodities
- costs of GM seeds
- low levels of insect damage in US fields in 1999

[1]http://biz.yahoo.com/rf/000113/baz.html

Reasons for Consumer Concerns About the Safety of Transgenic Plants

- Sick rats: Feeding rats GM potatoes that contained a gene for nematode/insect resistance resulted in reduced digestive capabilities.

- Ewen and Pusztai: The Lancet. Oct 16,1999:1354.

  – There is a great deal of dissent about the scientfic merits of this study

Reasons for Consumer Concerns About the Safety of Transgenic Plants

- Dead Butterflies[1]:
  - Milkweed leaves were dusted with pollen from Bt corn and fed to monarch butterfly caterpillars (it is the only thing they eat).
  - 44% died within 4 days, while none died that ate leaves dusted with non GM corn pollen

[1] Losey et al. Nature 1999. 399:214

Reasons for Consumer Concerns About the Safety of Transgenic Plants

- Dead Butterflies[1]:
  - Potted milkweed plants were placed on the edge of Bt corn fields and non Bt corn fields.
  - Near Bt corn: 20% of caterpillars died
  - Near non-Bt corn: 3% of caterpillars died
  - Other researchers have found that Bt corn varieties differ in the degree of toxicity of pollen towards caterpillars .

[1] Unpublished, Science. 1999. 286:1662.

Examples of Genetically Engineered Alfalfa

Gene	Source	Trait
SOD	Tobacco	drought/cold^{tol}
Protease Inhib.	Tob. Horn Worm	insect resistance
Cry1c	B. thurengiensis	insect resistance
Chitinase	Serratia	insect resistance
Protease Inhib.	Tomato	not tested
Bar	Streptomyces	herbicide^{res}

Examples of Genetically Engineered Alfalfa

Gene	Source	Trait
β-phaseolin	Bean	Storage protein
albumin	Sunflower	Nutritional quality
CAD	Alfalfa	Digestibility
Virus protein	Foot and Mouth Virus	Vaccination
Phytase	Bacteria	Nutritional quality

Introduction and expression of an insect proteinase inhibitor in alfalfa[1]

Objective: Express an insect proteinase inhibitor gene in transgenic alfalfa and evaluate plants for resistance to thrips.

Materials and Methods:

A. Used proteinase inhibitor gene from the tobacco horn worm.

B. Transformed alfalfa variety Regen-S using

[1]Plant Cell Rep. 1994. 14:31.

PERSPECTIVES

- Biotechnology has the potential to improve forage varieties for many important traits:
  - disease and pest resistance
  - enhanced nutritional qualities
  - increased tolerance to abiotic stress (cold, salinity)
  - new uses (bioenzyme factories, phytoremediation)
  - cultivation under more ‘sustainable’ systems (reduced applications of agrochemicals)

Limitations to the Use of Biotechnology for the Improvement of Crop Varieties

- Technology works best on traits that are controlled by single genes.
- For some crops (beans, pepper) it is very difficult to introduce genes or regenerate plants.
- For some crops, the varieties that can easily modified with biotechnology are not commercially acceptable.